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Použití různých metod přenosu a inokulace půd při obnově ekosystémů

Various methods of soil transfer and inoculation in restoration ecology

Bakalářská práce

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Prohlášení:

Prohlašuji, že jsem závěrečnou práci zpracovala samostatně, a že jsem uvedla všechny použité informační zdroje a literaturu. Tato práce ani její podstatná část nebyla předložena k získání jiného nebo stejného akademického titulu.

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Podpis

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Abstract:

Soil translocation is a method used in restoration ecology to either salvage habitats threatened by human activity or to restore disturbed habitats. There are various factors affecting the success rate of translocation operations which include the proper selection of a receptor site, method of soil manipulation, soil stockpiling and adequate aftercare. Different methods of soil stripping distinct in their success rates and application for use in habitat restoration, mainly in regards to their effect on the resultant community composition and financial costs. Translocations can result in decrease of biodiversity, but may be a viable option for locations of high conservation value where conservation in situ is not possible, allowing for quick restoration of mature ecosystems. Thorough surveys prior to and after the operation and sufficient allocation of resources are a key factor for successful translocation of soils and the associated biota. Additional research in the fields of invasions, comparison of methods and data analysis of translocation projects may improve the utilization of this technique in the future.

Key words: Soil translocation, translocation methods, soil stockpiling, nature conservation, restoration ecology, seed bank

Abstrakt:

Přenos půdy je metoda využívaná v ekologii obnovy k zachování společenstev ohrožených lidskou činností či k obnově narušených společenstev. Existuje řada faktorů ovlivňujících míru úspěchu přenosu, zahrnující vhodný výběr lokace pro cílové umístění půdy, způsob manipulace s půdou, skladování půdy a vhodná následná péče. Různé metody extrakce půdy mají za následek rozdílné míry úspěchu přenosu a liší se vhodností použití pro obnovu habitatů, obzvlášť ve vztahu k dopadu na výslednou skladbu společenstva a finanční náklady. Přenos půdy může vést ke snížení biodiverzity, ale může být úspěšně použit k zachování lokalit se zvýšeným výskytem chráněných druhů, kde zachování in situ není možné a umožňuje rychlé zotavení vyspělých ekosystémů. Důkladné průzkumy před a po provedení operace a dostatečné zajištění zdrojů jsou klíčovými faktory pro úspěšný přenos půdy a s ní spjaté bioty. Další výzkum na poli invazivních druhů, srovnávání využívaných metod a analýzy dat z proběhlých přenosů půdy může pomoci vylepšit využití této metody do budoucna.

Klíčová slova: Přenos půdy, metody přenosu, skladování půdy, ochrana přírody, ekologie obnovy, semenná banka

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1. Introduction

With recent rise of human population there is a growing demand for resources and thus the pressure upon natural environment increases. In order to fully or at least partially restore the ecosystems to their natural state and functionality, human intervention may be necessary in order to speed up the process. There are various methods used in restoration ecology for the reclamation of damaged or disturbed habitats, including soil translocation. To the end of the 20th century, soil translocations have been regularly conducted in the United Kingdom as a mean of compensation for the loss of valuable habitats, however the efficiency of the practice is still controversial and has high risk of failure (Bullock, 1998).

Many studies concerned with soil translocation methods tend to focus on areas and habitats affected by civil engineering, agricultural use or by surface mining. Example project can be found throughout Europe, among others in Austria (Bruelheide and Flintrop, 2000), France (Vécrin and Muller, 2003) and Norway (Antonsen and Olsson, 2005), but also in other parts of the world, such as Australia (Koch, 2007) or the United States (Hall et al., 2010).

Although the mechanisms of soil translocation may not yet be optimally defined and tested, there are already translocation operations which may be deemed successful but even these only prove that there are numbers of various factors affecting the outcomes and success rates of every translocation project – the compatibility of donor and receptor sites, timing of operations, method of soil stripping or even the reclamation practices used before. The purpose of this work is to investigate various methods of soil transfers used in the past and the factors affecting their outcome in order to determine future benefits of this practice for restoration ecology.

2. Defining translocation

As of now, there isn't a unified definition encompassing the entirety of a translocation process. According to Anderson and Groutage (2003) a translocation is '*the process of moving soils with their vegetation and any animals that remain associated with them in order to rescue habitats that would otherwise be lost due to some kind of development or extraction scheme*'.

This definition is in its essence shared by Box (2003), who further develops specific reasons for translocation to be carried out '*in order to rescue or salvage habitats that would be lost due to changes in land use, or to restore biodiversity to damaged, degraded or newly created sites*'. The above mentioned definitions somewhat differ from the definition given by the British Joint Nature Conservation Committee, stated as '*the movement of assemblages of species, particularly plants (including the substrates, such as soil or water, on and in which these species occur) from their original site to a new location*' (McLean, 2003), which focuses primarily on the plant communities and take the replacement of soil as a secondary, associated objective.

A definition used by Bullock (1998), which states that a translocation '*involves a wholesale removal of an assemblage of species from a site and the attempt to establish it as a functioning community at a new receptor site*' is – like the JNCC definition – also focused on the translocation of species, yet not exclusively on plants. However, translocation of animal populations in community translocation projects is rarely the case (Ryan, 2013). Invertebrates in the community have lower chances of being translocated since they can avoid the translocation itself but they are also more likely to sustain injury or even death in the process (Bullock, 1998).

This paper will use the definitions stated by Box (2003) and Anderson and Groutage (2003) as default, mainly due to their focus on soils and soil environment.

3. Rationale for soil translocation

There is a significant pressure upon finding balance between the needs for development and natural conservation, since – in order for development to be sustainable – there will always be a high demand for compensation or reversion of damage done in the process (Cowell, 1996) and translocation of soils and the associated habitats may in many cases be an efficient response to such a conflict (Bullock 1998).

Translocations may prove to be effective and economically advantageous way to salvage environments that have previously been disturbed, damaged or outright destroyed (Box, 2014), save species from condemned sites or revive declining populations (Fahselt, 2007). Although most translocations are conducted on sites of high conservation values (Bullock, 1998), they can also be performed to rescue mature ecosystems which deliver important ecosystem services, such as windbreaks, habitat connections, corridors for wildlife and various structures in the landscape. The same desirable traits of an ecosystem can be secured if the restored habitat achieves similar structure and function to that of the pre-existing habitat (Chambers et al., 1994), nonetheless, translocations are often a better alternative to habitat recreations, since they grant an immediate complexity of the environment, which is hard to achieve (for example through planting and sowing of seeds) and takes long to be established in newly created habitats (Box, 2014).

Although there are many beneficial aspects, it is important to note that translocations will always to some extent negatively affect the original community (Anderson and Groutage, 2003) and as such should never be used as a replacement for conservation in situ (Box, 1999). Fahselt (2007) suggests, that the destruction of a habitat usually seems more tolerable if the option of translocating a habitat is offered, yet such a decision should not be taken lightly and other alternatives should always be considered if a valuable community is in the way of human interests (Anderson and Groutage, 2003).

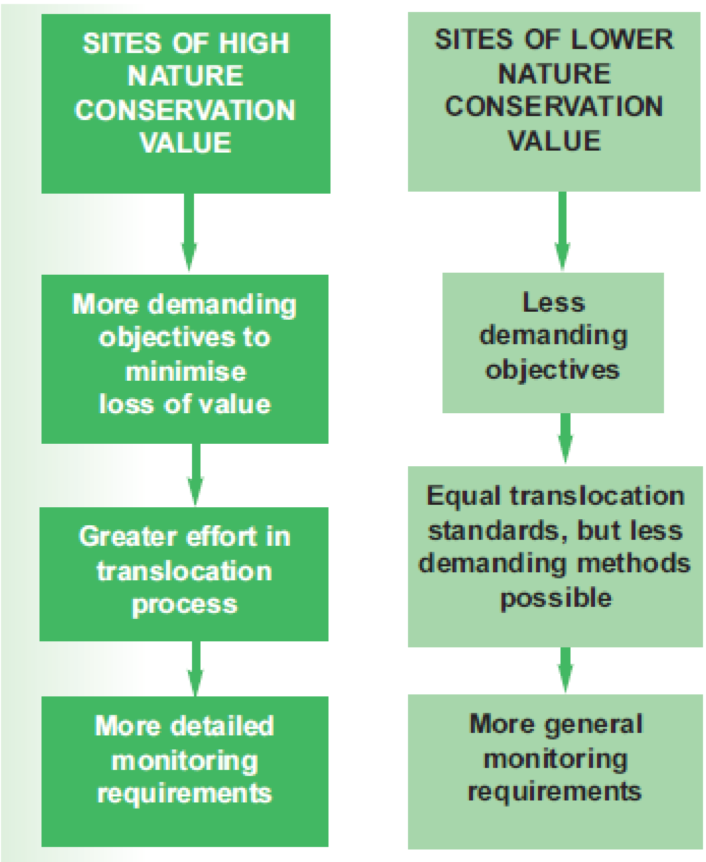

Fig. 3.1 Diagram indicating the required input based on habitat conservation value (Source: Anderson and Groutage, 2003)

4. The donor and receptor site

During soil translocation, the upper layers of soil are generally stripped from the donor site and redeposited at the corresponding receptor site (Hietalahti et al., 2005). These sites may vary in their respective location but also in physical and chemical properties. The receptor and donor site should, however, resemble one another as closely as possible in all environmental aspects, including slope, drainage, hydrology, nutrient contents (Box, 2003) and size, where the receptor site should have at least the same area as the donor site (Box, 1999). There are several types of suitable receptor sites and criteria for their selection.

4.1 Donor sites

Donor sites are usually selected for their value for nature conservation and which – without translocation projects – would be destroyed due to human interventions, such as mining (Anderson and Groutage, 2003). Problems for the donor site may arise in cases when translocation is used as a mean of restoring degraded or disturbed habitats (McLean, 2003) and where the removal of soils and the associated plant populations may cause degradation of the donor area, usually due to the inability of the remaining populations to sustain stable numbers (Bullock et al., 1997). Selecting habitat translocation for restoration purposes should therefore only be accepted if the survival of the donor site communities can be assured (Bullock et al., 1997) and if the translocation benefits will exceed the damage done to the donor site, usually in the means of net gain of biodiversity (McLean, 2003).

4.2 Receptor site in immediate distance

The receptor and donor site may exist within the same area in close proximity, for example in mining areas where topsoil is stripped from one location prior to mining and redistributed at the donor site, where mining has already ceased and which is being restored. Immediate return of topsoil in mining areas is desirable, since it prevents its degradation (see chapter 7. Topsoil stockpiling). Floral surveys may be carried out prior to mining in order to map vegetation, identify threatened species and provide future reference for restoration activities (Koch, 2007).

4.3 Corresponding receptor site

Where same-location return is not possible, areas of similar predispositions are being sought out, such as when woodland soils are redeposited onto receptor sites which have been used as pastures, but which have previously received woodland soil and are developing woodland vegetation (Hietalahti et al., 2005). However, isolated spots of translocated vegetation in, for example, arable landscape, are not encouraged and may greatly increase the risk of failure, due to the lack of connectivity with the original habitat and thus make migration of original plant and animal species into the area difficult or outright impossible (Box, 2014).

4.4 Receptor site of comparable origin

Soil translocations are often performed on sites with historically corresponding composition, but with current conditions affected by past management as it often happens with heathlands in the United Kingdom. The original heathlands have been converted to agricultural land used for growing crops and as pastures. Even though after abandonment heath started colonizing the pastures through natural spreading, the soil pH and organic material contents have already been altered (Pywell et al., 1995). In order to cope with different pH levels at the receptor site, part of the soil or even the bedrock may be excavated, for example in the case of low pH caused by spruce needle litter (Bruelheide and Flintrop, 2000).

4.5 Unsuitable receptor site

There are several case studies showing poor choice of the receptor site and which should be avoided, such as the Biggins Wood in Kent, where the soils and ground water conditions of the receptor site differed from the donor, Monkspath Meadow in Warwickshire, which placed the transferred soil on an already disturbed area or the Waddington Fell in Lancastershire, where the conditions of the receptor site were too wet compared to the donor site (Anderson and Groutage, 2003).

5. Soil stripping

In general, there are two main approaches towards stripping of soil from the donor site: loose-tipping, which involves mixing of the soil profile; and turfing, which leaves the soil profile undisturbed (Anderson and Groutage, 2003). This chapter will investigate methods, advantages and disadvantages of each approach.

5.1 Turfing

Turfing refers to the practice of lifting whole blocks of soil without mixing the respective soil profiles. Bullock, 1998; further divides turfing into three subcategories, characterized by the turf size and method of extraction:

a) **Hand turfing** – involves removal of turves by spades and generally results in smaller, thinner turves compared to those extracted by machinery.
b) **Machine turfing** – characterized by the use of earth moving machinery capable of excavating bigger blocks (0.07 – 0.5 m in depth) transported to the receptor site intact.
c) **Macroturfing** – during which large (1 m x 2 m, 0.15 – 0.45 in depth) soil monoliths are cut out and transported.

Turfing can be a suitable way to transfer various habitats, if appropriate preparations are made and if effective management after translocation is ensured (Good et al., 1999). Soil can either be placed in order to transfer the whole community (Hietalahti et al., 2005; Trueman et al., 2007; Craig et al., 2015) or used to inoculate desired species into a new habitat (Antonsen and Olsson, 2005; Aradottir, 2012).

Turfing generates fewer disturbances in the soil profile, though problems may arise with turves not being placed tightly next to each other, creating gaps (Bullock, 1998; Box, 1999). This problem can be mitigated by hand-filling of the gaps with appropriate soil from the donor site (Box, 1999; Bruelheide and Flintrop, 2000). One of the main setbacks of turfing is its high financial cost and alternatives with similar effectiveness need to be taken under consideration (Good et al., 1999).

5.1.1 Size of turves

The size and depth of turves is an important aspect in this method of translocation which significantly affects its outcomes. Too shallow turves will cause damage to rooting systems and may cause the loss of some species such as orchids. Deeper turves also have higher chance of successfully translocating the associated burrowing invertebrate fauna, for example yellow meadow ants (Bullock et al., 1997). Manual extraction of turves using spades is therefore not recommended (Anderson and Groutage, 2003).

Aradottir (2012) tested the effect of turf size in species introduction in order to find a suitable turf size for transplantation. While grasses and mosses were capable of thriving and spreading from turves of 5 x 5 cm in size, rhizomatous forbs only survived on turves of 30 x 30 cm whereas dwarf shrubs showed decline in all treatments, implying the optimal turf size for their translocation might be even greater than those tested in this study. Larger turves generally have greater species richness and are more suitable for translocation of rare species. If inoculation of native or more common species happens to be the objective, individual preferences of the desired species should be considered.

Fig 5.1 Grassland turf translocation (Source: Box, 2014)

5.2 Loose tipping

Loose tipping involves excavation and spreading of soil over the designated area (Bullock, 1998). It may also include turf transfer with subsequent rotovation and spread over a larger area compared to the original turf area (Good et al., 1999). Loose tipping causes higher disturbance in soil profiles and may encourage early succession pioneers and unwanted weeds to thrive at the translocated area (Bullock, 1998), but may be more suitable for certain habitats - while turfing is usually the method of choice for restoration of grassland communities (Box, 2003), loose tipping is preferred in woodland translocations, since roots and trees significantly complicate retrieval of undamaged soil monoliths (Hietalahti et al., 2005).

Fig 5.2 Woodland soil stripping (Source: Anderson and Groutage, 2003)

5.3 Stripping process and preparations

Soil is usually stripped to the depth of 30 cm (Rokich et al., 2000), although subsoil may be stripped as well, to the depth of 40 – 50 cm (Ferreira et al., 2015; Hall et al., 2010). This, however, is dependent on the depth of the soil seed bank, which is not universal – for example in a study on Australian Banksia forests, most seeds were found to be contained within the first 5 cm, with 97% of all seeds in the top 2 cm of the soil. Subsequent experiment revealed that when soil was stripped to 10 and 30 cm and then respread into a 10 cm thickness, the 10 cm stripping contained more seedlings per m^2 than the 30 cm stripping (254 and 81 seedlings per m^2 respectively) (Rokich et al., 2000).

Before translocation, the receptor site may be rid of some or all vegetation and soil, either via excavation (Bruelheide and Flintrop, 2000), topsoil stripping (Vécrin and Muller, 2003; Ferreira et al., 2015; Craig et al., 2015) or by the application of herbicides (Good et al., 1999). Pywell et al. (1995) suggest, that following the use of herbicides, the soil should be disturbed in order to promote better growth of plants shaded by the dead vegetation underneath.

Removal of vegetation from the donor site prior to soil stripping may be necessary for successful retrieval of soil when working in woodland areas (Craig et al., 2015), yet in some cases stripping of soil along with the vegetation present can be an advantageous factor. As presented by Ferreira et al. (2015), in Brazilian cerrados (savannas), many plants propagate through both root and stem fragments and soil translocated along with whole plants and their fragments proved to be a successful mean for reconstruction of a habitat which is often threatened by urbanization and mechanized agriculture.

6. Timing

The best time for soil stripping and translocation is in the autumn months, when soils are moist and still warm and when there is still enough potential for root re-establishment and growth before the winter season (Box, 2014). Stripping of soil in winter is not recommended, since it may disrupt seeds already in the process of germination (Rokich et al., 2000). There is greater risk connected with translocations operated in spring, because roots may not develop properly before the summer season. Translocations in summer tend to put a great stress on the disturbed soil after translocation, mainly due to a lack of rainfall and the water stress connected with it (Box, 2014).

Craig et al. (2015) observed the effect of season on translocation success for several years after translocation itself. The difference between spring and autumn operations was most visible in the first year after translocation, where the soil loose-tipped in autumn had smaller area of bare ground compared to that loose-tipped in spring. Translocation via loose-tipping during the spring growing season left many bulbs and rhizomes on the soil surface, exposing them to the outer environment, leaving them at greater risk of damage and drying out.

Similarly, Rokich et al. (2000) examined the difference between immediate stripping and translocation in autumn and winter, where the autumn translocation resulted in greater seedling recruitment (73 seedlings per 5 m^2) than in winter, where the number was only 5 seedlings per 5 m^2. However, Craig et al. (2015) also showed that both autumn and spring treatments had very little or no difference in vegetation cover after a ten year period.

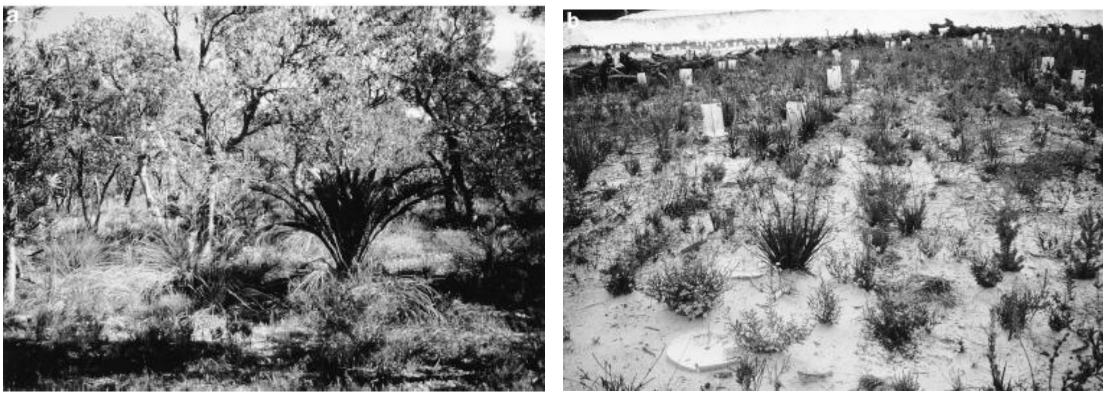

Fig. 6.1 Banksia woodland prior to mining (a) and after restoration from topsoil (b) (Source: Rokich et al., 2000)

7. Topsoil stockpiling

In opencast mining operations, land degradation and subsequent soil erosion are a common phenomenon, possibly leading to the loss of soil nutrients and the destruction of watersheds. Proper handling of soil in mining areas is therefore of uttermost importance. Topsoil stockpiling refers to the practice of removing soil and storing it for a period of time before it is returned to the original or a new site. However, stockpiling should only be carried out in cases where direct return is impossible or impractical to execute (Ghose, 2001).

7.1 Effects of stockpiling

Topsoil is biologically the most active part of the soil profile (Ghose, 2001). Stockpiling is shown to negatively affect the organic carbon contents of soil due to interruption in plant primary production and the associated secondary production of microorganisms (Stahl et al., 2002) (See Figure 7.1). Microbial populations can decrease up to eight times of the original population size within the first year of stockpiling. (Ghose, 2001).

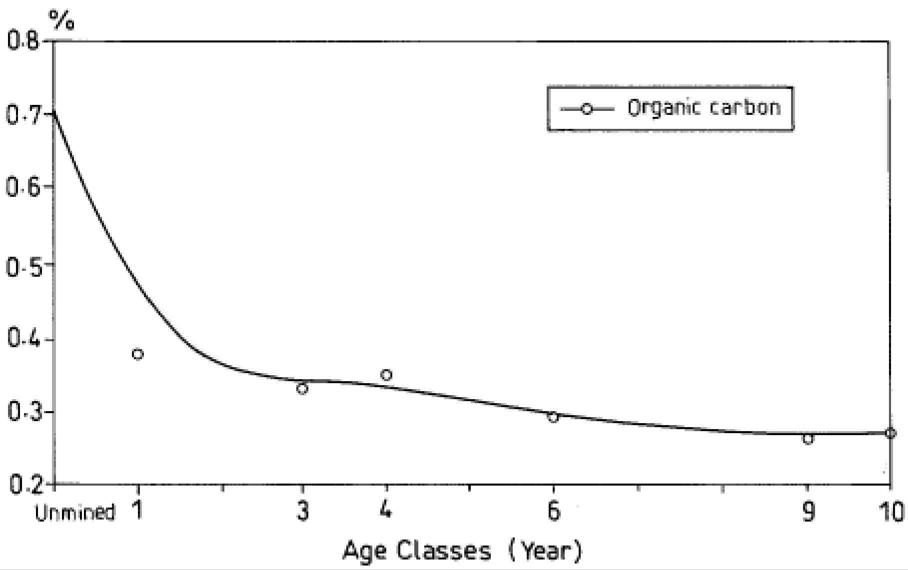

Fig. 7.1 Organic carbon variation in soil dumps of different age and in unmined soil (Source: Ghose, 2001)

Several studies also suggest that stockpiling negatively affects the viability and germinability of seeds within the soil seed bank – Rokich et al. (2000) conducted an experiment during which seeds were buried in soil that was directly returned and soil stockpiled for one and three months. Regardless of stockpiling time, the seeds in the stockpiled soil showed 50% decrease in viability compared to directly returned soil. Significant was also the decrease in species richness in soil stockpiled for one and three years, where the number of species was reduced to 78% and 61% of the original diversity, respectively. Rivera et al. (2012) ran a similar project which showed 40% seed mortality in the first six months of soil stockpiling, with seeds located on the surface or in the first 5 cm of soil affected more often than those buried deeper in the profile.

7.2 Conditions for topsoil stockpiling

If stockpiling of soil is necessary, it should be stored on stable area and with enough protection from contamination, compaction and water and wind erosion. Stockpiled heaps must be constructed with respect to soil type, with light, sandy soils reaching heights of maximum 5 m and heavy clay soils reaching 1 m at maximum and providing the biggest possible surface area. It is recommended to rip the newly formed stockpiles to prevent compaction and allow water infiltration, provide low maintenance plant cover and keep a good heap management. Assessment of shelf-life - the time, during which stockpiled topsoil is still capable of supporting plants without any biological reclamation - should also be done prior to any soil stripping in order to plan time management of soil translocation operations (Ghose, 2001).

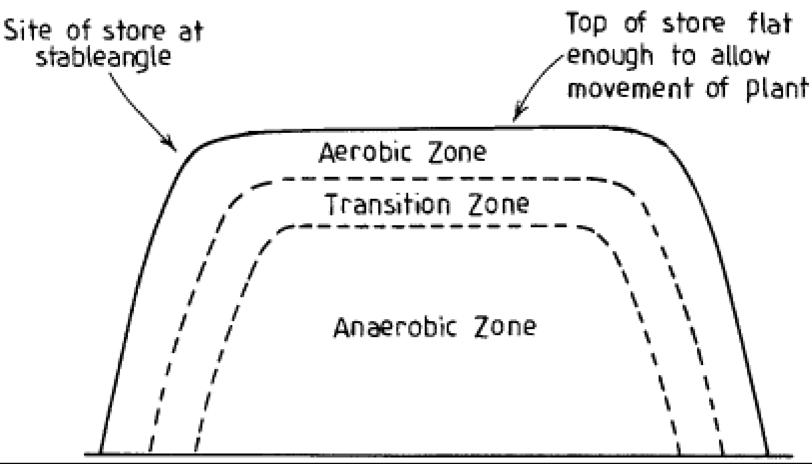

Fig. 7.2 Schematic diagram of topsoil storage heap (Source: Ghose, 2001)

8. Management of translocated soil

Following the placement or spreading of soil, the translocated material has to go through further processes in order to ensure successful restoration of the original habitat, especially by the means of landscaping – a field of restoration ecology, which has recently seen a notable range of improvement (Koch, 2007).

8.1 Compaction

Compaction of soil is a problem commonly encountered in any operation involving moving of soils, mainly due to heavy machinery travelling over its surface (Ghose, 2001). Wheeled-over soil may completely lack pores in the first few centimetres and continual travelling of machinery causes soil density to increase further. Internal soil strength only has certain maximum capacity and exceeding it will lead to damage to soil structure and its properties, such as air permeability and the gas exchange connected to it, loss of filtering capacity and decrease in buffering potential. Insufficient water conductivity leads to creation of water bodies on the surface and may result in undesirable soil erosion (Horn et al., 1995).

Compaction may sometimes be carried out on purpose as a result of management legislation. The Surface Mining Control and Reclamation Act (SMRCA) applied in the United States battled the initial problems with erosion in surface mining operations through recommending compaction and quick revegetation as a reclamation technique. However, this practice often resulted in the creation of pastures dominated by aggressive legumes, not allowing the return of the former vegetation present (Hall et al., 2010).

8.2 Soil restoration

Restoration of soil properties to the state prior to compaction may be a challenging task due to some processes being irreversible (Horn et al., 1995). The easiest way to prevent soil compaction is avoidance or reduction of heavy machinery travelling over the translocated soil (Ghose, 2001; Craig et al., 2015), yet where such compaction is unavoidable, ripping may loosen the soil structure, restore water infiltration and artificially create rootzones for plants (Kew et al., 2007). Secondary ripping eases the soil compaction after the soil is returned and minimizes water erosion before the development of vegetation. If fertilization is necessary after the translocation, helicopters can be a useful tool in spreading of fertilizers without causing additional compaction (Koch, 2007).

Fig. 8.1 Soil ripping machinery restoring the compacted ground (Source: Koch, 2007)

8.3 Effect on seed bank

A concern may arise for the dilution of the seedbank in ripped soils. Rokich et al. (2000) tested the effect of ripping on dilution of seeds within the topsoil of the *Banksia* woodlands, which (as mentioned above) have very shallow seed bank and are thus susceptible to reduction of seeds in favourable depths for germination. Measuring the seedling emergency in both ripped and unripped soils, no significant difference was found between the two treatments. This finding is of high importance for restoration ecology in general, since ripping of both soil and subsoil is a widely used practice for relieving of compaction.

9. Case studies

Not many translocations have been conducted both as turfing and as loose-tipping to provide comparison for the two techniques (Anderson and Groutage, 2003). Following are three studies showing the limits and advantages of both methods and investigating possibilities for improvements in future projects.

9.1 South Middlebere Heath, Dorset, UK (Pywell et al., 1995)

9.1.1 Introduction

A study comparing methods for translocation of heathland communities onto abandoned grasslands in order to assess their efficiency for restoration. Other methods of restoring heathlands were used in this study, but since they did not execute actual moving of soils, they will not be mentioned in this chapter.

9.1.2 Methods

Both turves and scraped topsoil used for transfer were obtained from the same area 11 km away from the receptor site. Prior to translocation of loose tipped topsoil, the soil from the receptor site was stripped to the depth of 50 mm and then covered with topsoil with rate application between 22 and 26 kg/m^2 and subsequently mixed with the soil of the receptor site in order to achieve better contact with soil seed bed. In the turfing treatment separate turves (1.5 m x 2.3 m x 150 mm in size) were transported to the receptor site and relaid, using an excavator. In this treatment, there was a necessity of watering the turves in order to counter to the negative effect of summer droughts.

The success of both methods was measured by the relative emergence of seedlings on each of the treatment plots. All of the species present at the donor site were present at both the plots with topsoil application and the transferred turves, however the topsoil application plots showed a different relative proportion of species compared to the donor site. The author attributes this change to the difference in drainage of the donor and receptor site, but also to the disturbance caused by this method of transfer. On the other hand, turfing showed the same relative abundance of species and quickly recreated the heathland habitat.

9.1.3 Results

In this study, both topsoil spreading and turfing were shown as useful tools in habitat restoration, with spreading having the potential of recreating areas larger than the donor area as opposed to turfing, however, the transport of large blocks allows the soil to retain some of its former drainage and water regimes and may introduce some edaphon from the original site. Turfing, despite its value for restoration, has been evaluated as a very costly procedure, requiring good planning, technology and skilled specialists to oversee the translocation. While soil spreading is a useful method for restoring large areas, turfing is recommended as a way of restoring visually sensitive environments and to provide stepping stones promoting growth of desired flora and for the introduction of its native species.

9.2 Blaengwrach farm, Wales, UK (Good et al., 1999)

9.2.1 Introduction

Acknowledging the financial strains of turfing, this study provides comparison of a whole turf translocation and fragmentation of turves and their subsequent rotovation into the soil at the receptor site. Donor turves were obtained from a site 1 km away from the receptor site, which was very similar in aspects of slope, hydrology and management history, with vegetation mapping done at both sites to evaluate translocation success rate. The receptor site was sprayed with herbicides to eliminate former vegetation and the plots were to rotovated.

9.2.2 Methods

The transfer was carried out in autumn. Turves from the donor site (1.5 m x 2 m x 10 – 20 cm) were transported on palettes and immediately laid down either intact or they were manually broken down, respread to twice their original area and rotovated into the prepared soil. Since there were wetter and drier areas on both sites, the corresponding plots were placed at the receptor site accordingly. The transferred plots were fenced to limit cattle and rabbit access and permanent control plots were set up inside and outside the fenced areas.

9.2.3 Results

Nine months after translocation, the whole turf plots were more even in texture and had smaller area of bare ground compared to the rotovated turves, however, this difference was no longer noticeable after the third growing season. The sites were annually surveyed to assess the number of species present at the plots. Four years after translocation, the success rates were calculated for dry and wet sites, with 49% success rate of whole turf transfer at the dry sites (37 out of 72 of the donor site species still present) and 54% success rate at the rotovated turf plots (39 species still present). The wet sites had higher success rates, with 71% at whole turf plots (60 species still present) and 62% at rotovated ones (55 species still present). The species richness per plot was usually very similar in the two methods, with both eventually displaying traits of both the donor and receptor site. The similarity in success rates is important for future translocations, since whole turf translocation may not always be an option – spreading turves and rotovating them into the ground is cheaper and often easier to conduct, because they can cover larger areas and because undisturbed turves can be hard to obtain, especially in rocky terrains or habitats with significant slope.

9.3 Cantenbury, Kent, UK (Hietalahti et al., 2005)

9.3.1 Introduction

In soil translocations, woodland habitats are among those which are translocated rarely. This study analyzes different methods of translocating woodland soils and its effects on mineralization and community composition.

9.3.2 Methods

Five treatments were applied to a deciduous woodland soil – a control plot was set up in undisturbed woodland, two woodland plots were loose tipped and turfed respectively in situ and two plots – one loose tipped and one turfed - were established ex situ. The soil was stripped to the depth of 20 – 25 cm, in the turfing technique blocks were extracted in two halves of 1 x 0.5 m in size.

On each of the plots, carbon mineralization was measured monthly during a five month period. Nitrogen mineralization was monitored via soil cores, with one soil core extracted immediately to obtain t=0 for comparison. Effect of disturbance was also analyzed in polyethylene tents, where soil cores were subjected to disturbance and their nitrogen and carbon mineralization was measured. Soil disturbance was simulated by passing of the soil through sieves of 25 mm for moderate disturbance and 10 mm for high disturbance.

9.3.3 Results

In the field experiments, soil respiration was measured to be higher during winter in the woodland control than in both of the ex situ treatments, while during spring and summer months there was no significant difference. Net mineralization of nitrogen was calculated to be higher in the woodland controls and in situ treatments rather than in the ex situ plots.

Measuring the amount of nutrients in the top 10 cm of soil showed that in loose tipping treatments the amount of nitrogen and organic carbon is lower than in other treatments, which is probably the result of mixing of soil profiles and their nutrients during the procedure. Net mineralization of nitrogen was recorded to be the lowest in all loose tipping plots regardless of their position, correspondingly undisturbed soil cores had higher respiration rates while moderately and highly disturbed cores showed similar rate of respiration, showing that disturbance did not increase mineralization in soils. The soil core experiment stresses out the importance of the top organic layer, because the undisturbed soil cores required less watering to attain water field capacity than the disturbed ones due to their top layer retaining moisture.

In the ex situ treatments, a major role was played by the sudden loss of forest canopy, which lead to greater throughfall and subsequent waterlogging, which also results in the loss of nitrogen. Without the canopy there is smaller competition for light, giving advantage to non-woodland, ruderal species usually limited by this factor. The conditions were probably also aggravated by the manipulation during transport which - in loose tipped soils - was coupled with increase in soil bulk density connected to this type of soil translocation, giving further emphasis on the necessity of careful handling of translocated soils and on the reduction of distance between donor and receptor sites.

10. Planning and assessment

Soil translocation by no means ends with the placement of soil at the receptor site, since post-translocation management plays a major role in future outcome of a given translocation process and has to be planned properly in advance along with the course of the procedure itself. Even if the translocated soil is managed in the same manner as at the donor site, habitats are dynamic systems and changes in both plant and animal communities are likely to occur (Bullock, 1998). Proper assessment of habitat translocations prior to the translocation itself is therefore a key factor and should not be underestimated. As stated by Anderson and Groutage (2003), sufficient time should be allocated to surveying of the translocated area, with at least two years of surveys prior to any intervention into the selected habitat and a minimum of ten years of continuous monitoring after the operation, although in certain ecosystems - such as woodlands – a longer period of about twenty to twenty five years may be required.

Unfortunately, most habitat translocations aren’t undertaken as a long term, planned operations, but rather a last resort action, without sufficient time to evaluate all involved factors. As of now, there are no appropriate standards for assessing success rates of soil translocations and these are yet to be set (Bruelheide and Flintrop, 2000), since success rates are always affected by the definition the group conducting the operation create for their particular project (Trueman et al., 2007). A great drive for current development and planning projects is the concept of ‘no net loss’ of biodiversity, requiring the replacement of lost ecosystems with ecosystems of the same composition and value. Translocations are of high importance to this concept, because new, mature ecosystems cannot be created as quickly as they are being destroyed. For this concept to work, a standardized and universally accepted definition of biodiversity has to be established in order for ecologists to be able to characterize biodiversity changes. Subsequently, data should be collected and analyzed for each translocated habitat to predict outcomes and facilitate development of future translocations (Box, 2014).

In comparison with other conservation projects, soil translocations have a great advantage in the fact, that their assessment objectives can be derived directly from the donor site and can obtain up to date, relevant reference (Bruelheide and Flintrop, 2000). To get the highest possible standards for execution of any translocation project a good communication between all sides involved is crucial. Misunderstandings between ecological specialists designing the project and civil engineers responsible for the field works itself can have a great impact on the translocation outcomes (Anderson and Groutage, 2003).

11. Comparison of restoration techniques

Apart from soil translocations, there are other means of habitat restorations commonly used for the purposes of restoration ecology.

11.1 Natural succession

The easiest method of restoring vegetation is by natural succession, especially in grasslands (Prach and Hobbs, 2008). Compared to translocations, this method is very cheap and doesn't require complicated procedures and equipment (except for minor disturbance to promote growth of new plants) (Manchester et al., 1999). On the other hand, natural succession is a very slow process and usually dependent on either soil seed bank or adjacent vegetation, which may be composed of ruderal, alien or otherwise unwanted species and may not result in the creation of the target community (Prach and Hobbs, 2008). Especially in restoration of habitats on agricultural land, where the soil can be degraded and where natural succession tends to depend on seed rain from a fragmented habitat, the final outcome may be very unpredictable (Manchester et al., 1999) and can lead to a transformation into a different and unintended vegetation type (Pywell et al., 2002). Still, thanks to its cheap and non-demanding nature, natural succession can be a good option for areas of low environmental stress and low productivity (Prach and Hobbs, 2008).

11.2 Shoot harvesting

Alternate low cost option for habitat restoration in e.g. heathland communities is the collecting of plant shoots. Pywell et al. (1995) compared this method to both loose tipping and turfing and although both of the mentioned procedures had more numerous seedling emergence and plant diversity, regeneration from shoots showed a good restoration potential, if heathland species not transferred by shoots are supplied, for example by additional sowing of seeds or support of plants grown in containers. Shoots are very cheap, renewable and easily accessible source of heathland propagules, may cover large area of restored land and limit the growth of weeds and other unwanted species, resulting in decrease of invasions known to occur in soil translocations (Bullock et al., 1997). Their harvesting also doesn't have a devastating effect on the donor area, which – in soil translocations – is inevitable (Pywell, 1995).

11.3 Hay transfer

In the restoration of meadows, another used approach is the transferring of hay, although not a lot of research has been conducted in this field (Manchester et al., 1999). Combination of topsoil removal and hay transfers has proven to be a good way to restore desired vegetation cover on grassland fens and bogs (Rasran, 2007). If hay is supplied from a well selected area with the same species composition as the target community, it will contain seeds of the same ecotype and will transfer them to the new location. Still, it is difficult to predict the seed amounts and distribution in the hay, seeds may be in inappropriate stage of ripeness and the success of this procedure is also affected by weather conditions and time of hay storage (Manchester et al., 1999).

12. Status of translocations as a restoration tool

Translocations in general are very attractive to developers and all policies connected to them will greatly affect the housing, transportation and other industries. In Great Britain the number of requests for translocations grows, yet so far the practice is considered risky and damaging and not suitable as a replacement for in situ conservation, which earned them very strong opposition from conservationists, especially when sites of high conservation value are being discussed (McLean, 2003).

There are several reasons for the discouragement of soil translocations and those should always be weighed against the arguments supporting the practice (Bullock et al., 1997). Translocations will always result in the destruction of the donor site and the translocation will lead to severance of the affected area not only from its natural but also cultural associations (McLean, 2003). In most – if not all – translocations some level of habitat fragmentation occurs (Bullock et al., 1997) and the disruption or loss of habitat mosaic may severely affect animals inhabiting the area (McLean, 2003). The effect on landscape may also be in the terms of aesthetics, since the translocation will have an impact on the natural patterns of the countryside. This particular aspect may often appeal more to the interests of the public than the conservation issues connected to the operation itself (Bullock et al., 1997).

The loss of species and diversity was already discussed in previous chapters and they are one of the major aspects discussed when translocations are being proposed. Losses of species may be caused by financial strain, which doesn’t allow for large enough area to be translocated, which puts pressure on the populations which were transferred and on the remaining populations alike due to the decrease in living space and number of individuals present (Bullock et al., 1997).

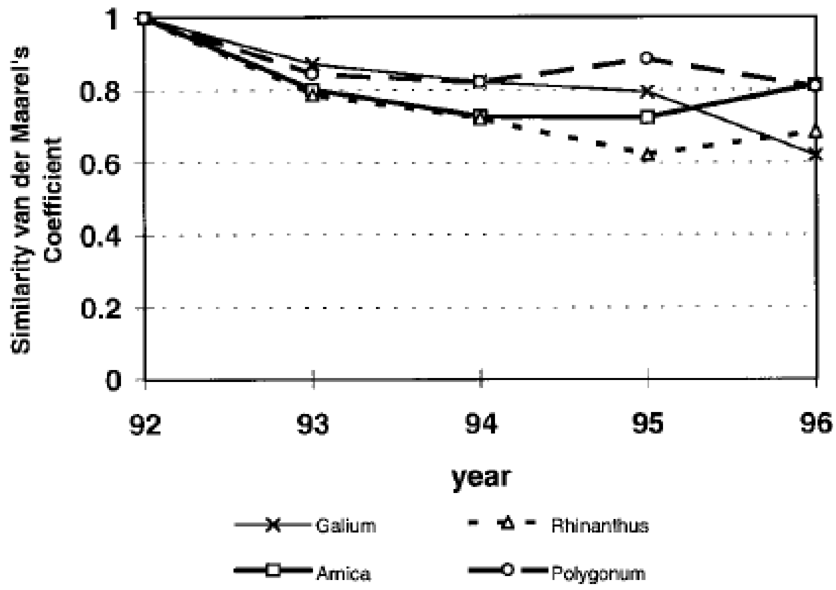

Fig. 12.1 Changes in similarity of four vegetation types relative to their initial state in the Harz mountains transplantation (Source: Bruelheide and Flintrop, 2000)

In every translocation there is also a risk of unwanted spread of invasive species not only into the relocated segment but also from the translocated area into its new surroundings. The general rule states that the chances of invasion increase with the rise of the ratio of edge to area. Although invasions are known to occur in existing translocation projects, they were never specifically studied for the purpose of translocations and thus leave space for further investigations (Bullock et al., 1997).

13. Summary

Soil translocation can be useful mean of conserving sites of high conservation value, which would otherwise be destroyed or irreversibly damaged by human intervention (Box, 2014). However, it is important to note that translocations themselves are damaging and should not be viewed in the sense of mitigation which reduces the extent of human impact, but rather as a compensation for the impact already inflicted (McLean, 2003).

Every translocation will result in certain deterioration of the original community (Anderson and Groutage, 2003) and location, whether related to the species composition and abundance or to the context of its landscape and history (Bullock et al., 1997). If improperly handled, the translocated soil may become compacted and prevent proper execution of functions of the soil environment, such as the circulation of gases, water infiltration and creation of favourable conditions for plant growth (Horn et al., 1995). Stockpiling of soil may lead to similar changes in soil (Ghose, 2001), along with the loss of organic carbon and microbial communities (Stahl et al., 2002) and reduction of seed viability and germinability (Rokich et al., 2000; Rivera et al., 2012).

On the other hand, if the destruction of the original habitat is inevitable and in situ conservation isn't an option, with proper preparation and allocation of sufficient resources, translocation may be a viable compromise between the pressure on development and conservation policies (Anderson and Groutage, 2003; Bullock, 1998). Translocations allow for quick restoration of mature ecosystems, which would take years to be recreated (Box, 2014) and thus offer the same or at least similar ecosystem services (Chambers et al., 1994).

Proper investigation prior to any translocation and adequate aftercare and monitoring are key factors for achieving satisfactory results of any operation involving the moving of soils and the associated habitats (Anderson and Groutage, 2003). These include a proper choice of the receptor site (Box, 2003), suitable method of soil stripping for the habitat under consideration (Box, 2003; Hietalahti et al., 2005) and staff (ecologists, engineers, etc.) experienced in the matters of soil translocations (Anderson and Groutage, 2003).

Although there is a number of studies showing different methods of translocating soils (Vécrin and Muller, 2003; Koch, 2007; Hall et al., 2010), not many studies actually compare them (Anderson and Groutage, 2003). There also isn't a unified definition of success (Bruelheide and Flintrop, 2000) or of biodiversity (Box, 2014), which further complicates the setting of standards for successful translocation procedures. For the future of soil translocations there are several fields which could be investigated to support and improve the knowledge about this practice, including comparison of different methods, collecting and analyzing data in current and future translocation projects and investigation of invasions and colonization in translocations.

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